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NSV 11749: Symbiotic Nova, Not a Born-Again Red Giant

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ABSTRACT

NSV 11749 is a little-studied variable star, discovered by W. J. Luyten, which had a long-duration outburst around the year 1903, reaching blue magnitude 12.5 at maximum. Following the outburst, it has apparently been quiescent at about blue magnitude 17 for the past century. It was recently suggested that NSV 11749 may have been a low- or intermediate-mass star that underwent a final helium shell flash, making it temporarily a "born-again" red giant. If so, it would be only the fourth known member of this class, along with V605 Aql, FG Sge, and V4334 Sgr. However, our newly obtained optical and near-IR spectra of the object show that it is instead a symbiotic binary, with strong Balmer and He I–II emission lines, combined with a cool red-giant companion of spectral type M1-2 III. The 1903 outburst was most likely a symbiotic nova event, of which less than a dozen are known at present.

Subject headings: novae, cataclysmic variables; stars: symbiotic; stars: individual (NSV 11749, V4334 Sgr, V605 Aql, FG Sge, V1329 Cyg)

1. Introduction: Born-Again Red Giants

Near the end of its life, a low- or intermediate-mass star leaves the asymptotic giant branch (AGB) and evolves rapidly across the HR diagram to the top of the white-dwarf (WD) cooling track. As the star ascends toward the tip of the AGB, it begins undergoing periodic helium-shell thermal pulses. Depending on the relative timing of the pulses and the departure from the AGB, the star may experience a helium final flash after it has already approached or reached the top of the WD sequence. In this case, the star quickly retraces its evolution and temporarily becomes a red giant once more, a so-called "born-again" red giant. The final-flash scenario was first described theoretically by Iben et al. (1983).

There are three known objects—all of them central stars of extremely faint planetary nebulae—that appear to have undergone born-again final-flash events during modern astronomical history: V605 Aquilae and V4334 Sagittarii (Sakurai's Object), which evolved very rapidly and are generally considered to represent very late thermal pulses (VLTPs), and FG Sagittae, which evolved more slowly and represents a late thermal pulse. There is an extensive literature on these objects and the underlying theory (e.g., Clayton & De Marco 1997; Lawlor & MacDonald 2003; Herwig 2005; Schönberner 2008; Bond et al. 2013; and references therein).

2. NSV 11749

NSV 11749 is a little-studied variable star that was discovered by Luyten (1937) in the course of his Bruce Proper Motion Survey, and was originally designated AN 799.1936 Aquilae. As recounted by Williams (2005), Luyten found NSV 11749 to have had blue magnitudes of 13.5 and 17 on plates taken in 1903 and 1934, respectively. Unfortunately, Luyten never published a finding chart, and the coordinates that he provided were only

approximate. Williams (2005), however, was able to recover NSV 11749 on plates in the Harvard collection, including the Bruce plate pair on which Luyten had marked the variable. Williams gave improved coordinates, as well as a light curve based on 175 Harvard plates obtained between 1888 and 1988. The star was first detected at blue magnitude 14 in 1899, and reached a maximum of 12.5 mag in 1903. It remained bright for 4 years, declined back to 14.5 mag in mid-1911, and then fell below the plate limit apart from four detections on deep plates at about 17th mag between 1934 and 1949. Williams suggested that NSV 11749 might have been a slow nova or an FU Orionis-type young stellar object.

However, Miller Bertolami et al. (2011) recently made the novel suggestion that the outburst of NSV 11749 was a VLTP event similar to those undergone by V605 Aql and V4334 Sgr, on the basis of similarities of the outburst light curves of the three objects. At the request of these authors, the DASCH team at Harvard (Grindlay et al. 2009) determined an accurate position for NSV 11749 from plates taken during the 1903 outburst. There is a stellar-appearing source at the DASCH position in various modern sky surveys, including the USNO-NOMAD catalog (Zacharias et al. 2004; J2000 position 19:07:42.36, +00:02:51.0; $B = 16.6$, $R = 14.1$), IPHAS (González-Solares et al. 2008; $r' = 14.5$, $i' = 13.1$, $H\alpha = 13.0$), 2MASS (Cutri et al. 2003; $J = 10.8$, $H = 9.7$, $K_s = 9.4$), and *WISE* (Wright et al. 2010; [3.4] =9.1, [4.6] = 9.1, [12] = 8.7, [22] = 8.4). Figure 1 presents a finding chart for this object.

This object was also detected as an Hα emission-line star, designated HBHA -0201-01 ($V \simeq 15.1$), in an objective-prism search carried out with plates obtained with the Hamburg Schmidt telescope in the years 1964–1970 (Kohoutek & Wehmeyer 1999). The large value of $r' - H\alpha$ in the IPHAS survey is consistent with strong Hα emission.

There is no known planetary nebula surrounding NSV 11749. The SIMBAD database identifies NSV 11749 with the bright *IRAS* source 19050+0001; however, inspection of the

IRAS images shows that the infrared source is actually a pair of bright stars about 3′ north of NSV 11749.

3. Observations

If the suggestion of Miller Bertolami et al. (2011) were correct, NSV 11749 would be only the fourth known born-again event, and would be of particular interest as a post-FF object that has evolved more than a full century since its outburst. In order to investigate its nature, we requested spectroscopic observations with the SMARTS 1.5-m telescope at Cerro Tololo Interamerican Observatory and its Ritchey-Chretien spectrograph. Spectra were obtained by the SMARTS service observers on 2012 May 28 (UT) with grating setup 26/Ia (covering 3660–5440 Å at a resolution of 4.3 Å), and on 2012 September 9 with grating setup 47/Ib (5650–6970 Å, resolution 3.1 Å). Exposure times were 3×300 s and 3×400 s, respectively. A spectrophotometric standard star was also observed on both nights (LTT 4364 and Feige 110, respectively), allowing flux calibration of the NSV 11749 spectra. Since the second night was reported to be non-photometric, we have scaled the spectrum from that night to match the extrapolated flux level of the earlier blue spectrum.

The optical spectra are plotted in Figure 2. The top panel shows the spectrum scaled to show the emission lines, and the bottom panel expands the same data to show the continuum. If NSV 11749 had been a born-again event like V605 Aql or V4334 Sgr, we would expect to see an extremely hydrogen-deficient object; for example, at the present time V605 Aql shows strong emission lines of [O III], a complete absence of Balmer emission, and weak emission features of C IV arising from a dust-obscured hot Wolf-Rayet planetary-nebula nucleus (e.g., Clayton et al. 2006).

Instead, NSV 11749 shows very strong emission lines of the Balmer series, along with

He I and He II. There are no forbidden lines detected. The spectrum also shows a broad emission feature at about 6825 Å. Emission at λ6825 is a feature seen only in symbiotic binaries (e.g., Webster & Allen 1975; Allen 1980), and has been identified with emission from the strong O VI 1032 Å resonance line that has been Raman-scattered by neutral hydrogen (Schmid 1989, 2001; Lee & Kang 2007). There is thus little doubt that NSV 11749 is a symbiotic star, in which a hot compact star, usually a WD, accretes from the wind of a late-type red giant. The overall pattern of emission lines in NSV 11749 is fairly similar to that seen (in quiescence) in the symbiotic nova V1329 Cyg (Kenyon & Fernandez-Castro 1987, Fig. 1b; Munari & Zwitter 2002, Figs. 192 and 193).

The bottom panel in Figure 2 zooms in on the continuum, which, although noisy, clearly shows molecular bands of TiO, indicative of an early M spectral type. To confirm this classification, we superpose a scaled spectrum of the M1 III standard star σ Virginis (HD 115521), obtained from the Munari & Zwitter (2002) atlas[1], which provides a reasonable match. We estimate a reddening of NSV 11749 of $E(B-V) \simeq 0.75$ (based on Schlegel, Finkbeiner, & Davis 1998 as well as the discussion in the next paragraph), and we applied this amount to the σ Vir spectrum, using the formulae of Cardelli, Clayton, & Mathis (1989).

On 2012 September 20, we obtained a near-infrared (NIR) spectrum of NSV 11749 with the Folded-port InfraRed Echellette spectrograph (FIRE; Simcoe et al. 2008, 2010) on the 6.5-m Magellan Baade Telescope. We used the low-dispersion, high-throughput prism mode, and completed an ABBA dither sequence. Each integration was in "Sample Up the Ramp" mode (10.6 s). The spectra span 0.8–2.5 μm at a resolution ranging from 300–500. Immediately afterwards, we obtained a spectrum of the nearby A0 V star HD 177880B (HIP 93835) for the purposes of flux calibration and removal of telluric absorption features,

[1]The data were downloaded from `http://ulisse.pd.astro.it/\penalty\exhyphenpenaltysymbio_a`

as described by Vacca, Cushing, & Rayner (2003). Data were reduced using the FIREHOSE pipeline developed by R. Simcoe, J. Bochanski, and M. Matejek. The resulting spectrum is shown as a black line in Figure 3.

The NIR spectrum of NSV 11749 shows emission lines of the Paschen series and He I 10830 Å, superposed on a late-type absorption spectrum. We compared the absorption-line spectrum to a library[2] of standard stellar spectra obtained with the IRTF (Cushing, Rayner, & Vacca 2005; Rayner, Cushing, & Vacca 2009). We find a reasonable match of NSV 11749 with the M2 III standard star 87 Virginis (HD 120052), with an extinction of $E(B-V) = 0.75$ applied to 87 Vir, as plotted in red in Figure 3. There is an apparent broad emission line at 1.999 μm, which we have been unable to identify; it may be an artifact due to incomplete telluric feature removal.

4. Conclusion: Symbiotic Nova, Not Born-Again Red Giant

Our observations verify that NSV 11749 is a symbiotic binary, containing a compact hot object and a companion red giant with a spectral type of about M1–2 III. Its location in the IPHAS $r' - H_\alpha$ vs. $r' - i'$ diagram (Corradi et al. 2008) is consistent with a "stellar (S)"-type symbiotic, rather than a "dusty (D)" type, as is its lack of a strong mid-IR excess in the *WISE* photometry.

The eruption of NSV 11749 around 1903 may have been a classical symbiotic outburst, but both its large amplitude and long duration are more suggestive of a symbiotic nova (due to a thermonuclear runaway on the WD component). Less than a dozen symbiotic novae have been observed to date (e.g., Mikołajewska 2010; Tang et al. 2012). It would be of interest to determine the orbital period and other properties of this apparent new

[2]Available at `http://irtfweb.ifa.hawaii.edu/$^\sim$spex/IRTF_Spectral_Library/`

member of this rare class.

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Facilities: SMARTS 1.5m telescope, Magellan Baade Telescope

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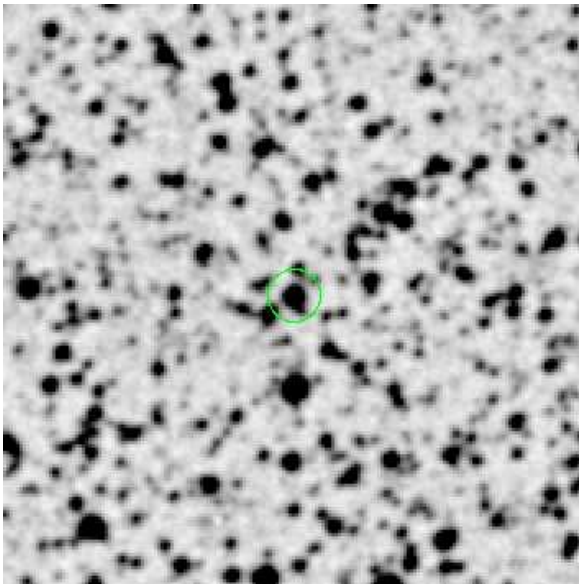

Fig. 1.— Finding chart for NSV 11749, from the Digitized Sky Survey red image. The field is $3' \times 3'$ and north is at the top and east on the left. *The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166.*

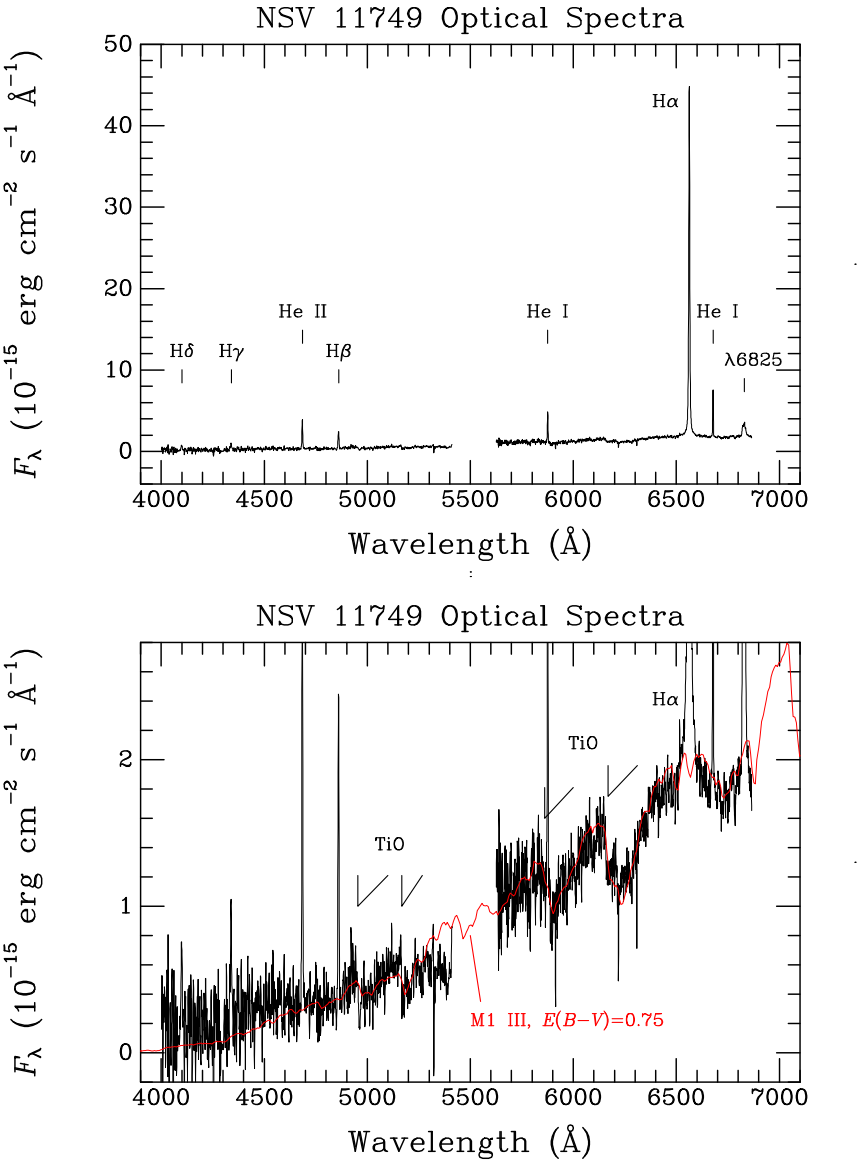

Fig. 2.— SMARTS 1.5m optical spectra of NSV 11749 (black line), with a 3-point boxcar smoothing applied. The spectra in the top panel are scaled to show the strong emission lines of the Balmer series, He I and II, and the broad λ6825 Raman feature characteristic of symbiotic binaries. Bottom panel scales the same data to show TiO bands in the continuum, belonging to a cool companion of the hot component of the binary. Superposed in red is a scaled spectrum of the M1 III standard star σ Vir, reddened by $E(B-V) = 0.75$, which provides a reasonable match.

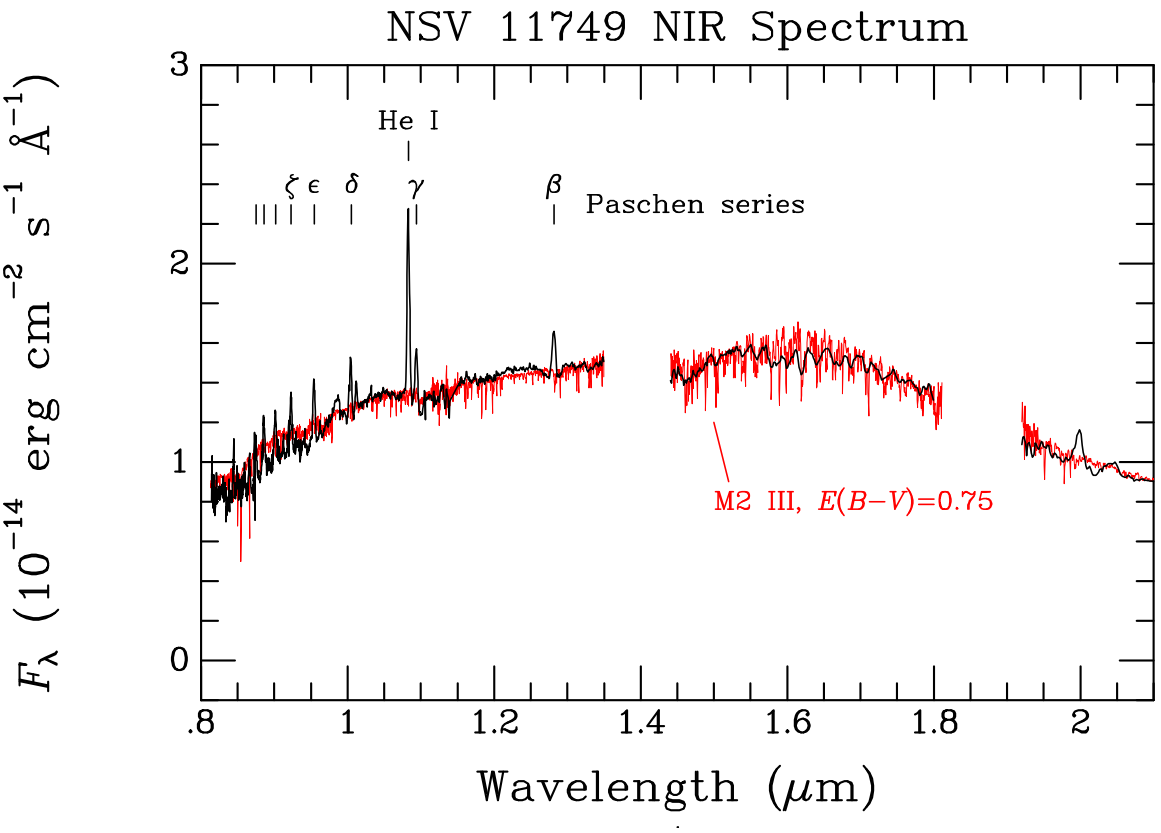

Fig. 3.— Magellan NIR spectrum of NSV 11749 (black line), showing emission of the Paschen series and He I 1.0830 μm. Also plotted (red line) is the spectrum of the M2 III standard star 87 Vir, reddened by $E(B-V) = 0.75$ and scaled to the flux of NSV 11749, which provides a good fit to the energy distribution.